

International  
**IR** Rectifier

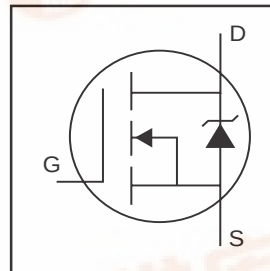
**AUTOMOTIVE MOSFET**

PD - 94753  
**IRFR3504Z**  
**IRFU3504Z**

HEXFET® Power MOSFET

#### Features

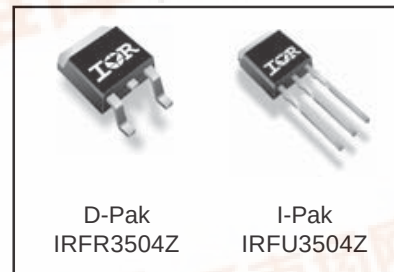
- Advanced Process Technology
- Ultra Low On-Resistance
- 175°C Operating Temperature
- Fast Switching
- Repetitive Avalanche Allowed up to  $T_{jmax}$



$V_{DS} = 40V$   
 $R_{DS(on)} = 9.0m\Omega$   
 $I_D = 42A$

#### Description

Specifically designed for Automotive applications, this HEXFET® Power MOSFET utilizes the latest processing techniques to achieve extremely low on-resistance per silicon area. Additional features of this design are a 175°C junction operating temperature, fast switching speed and improved repetitive avalanche rating. These features combine to make this design an extremely efficient and reliable device for use in Automotive applications and a wide variety of other applications.



#### Absolute Maximum Ratings

|                              | Parameter                                                  | Max.                     | Units |
|------------------------------|------------------------------------------------------------|--------------------------|-------|
| $I_D$ @ $T_C = 25^\circ C$   | Continuous Drain Current, $V_{GS}$ @ 10V (Silicon Limited) | 77                       | A     |
| $I_D$ @ $T_C = 100^\circ C$  | Continuous Drain Current, $V_{GS}$ @ 10V                   | 54                       |       |
| $I_D$ @ $T_C = 25^\circ C$   | Continuous Drain Current, $V_{GS}$ @ 10V (Package Limited) | 42                       |       |
| $I_{DM}$                     | Pulsed Drain Current ①                                     | 310                      |       |
| $P_D$ @ $T_C = 25^\circ C$   | Power Dissipation                                          | 90                       | W     |
|                              | Linear Derating Factor                                     | 0.60                     | W/°C  |
| $V_{GS}$                     | Gate-to-Source Voltage                                     | $\pm 20$                 | V     |
| $E_{AS}$ (Thermally limited) | Single Pulse Avalanche Energy ②                            | 77                       | mJ    |
| $E_{AS}$ (Tested)            | Single Pulse Avalanche Energy Tested Value ③               | 110                      |       |
| $I_{AR}$                     | Avalanche Current ①                                        | See Fig.12a, 12b, 15, 16 | A     |
| $E_{AR}$                     | Repetitive Avalanche Energy ③                              |                          | mJ    |
| $T_J$                        | Operating Junction and                                     | -55 to + 175             | °C    |
| $T_{STG}$                    | Storage Temperature Range                                  |                          |       |
|                              | Soldering Temperature, for 10 seconds                      | 300 (1.6mm from case)    |       |
|                              | Mounting Torque, 6-32 or M3 screw                          | 10 lbf•in (1.1N•m)       |       |

#### Thermal Resistance

|                 | Parameter                         | Typ. | Max. | Units |
|-----------------|-----------------------------------|------|------|-------|
| $R_{\theta JC}$ | Junction-to-Case                  | —    | 1.66 | °C/W  |
| $R_{\theta JA}$ | Junction-to-Ambient (PCB mount) ④ | —    | 40   |       |
| $R_{\theta JA}$ | Junction-to-Ambient               | —    | 110  |       |

HEXFET® is a registered trademark of International Rectifier.

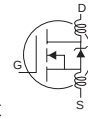
www.irf.com

# IRFR/U3504Z

International  
IR Rectifier

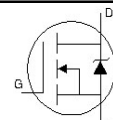
## Electrical Characteristics @ $T_J = 25^\circ\text{C}$ (unless otherwise specified)

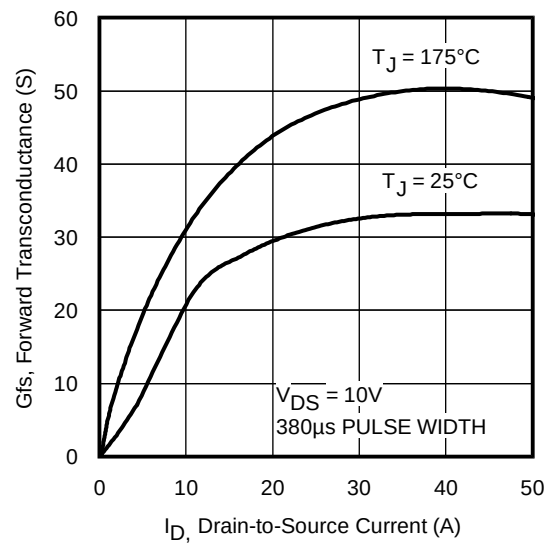
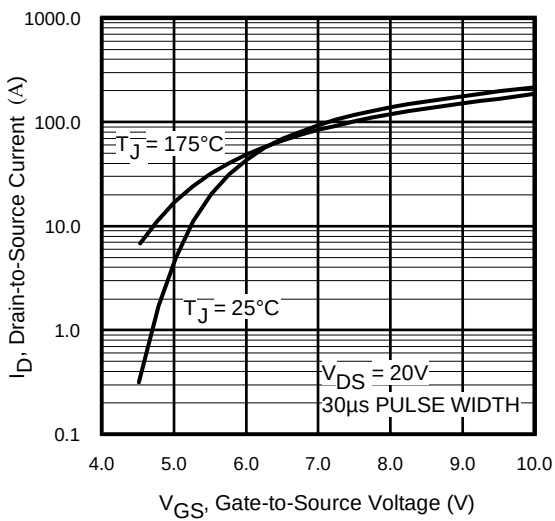
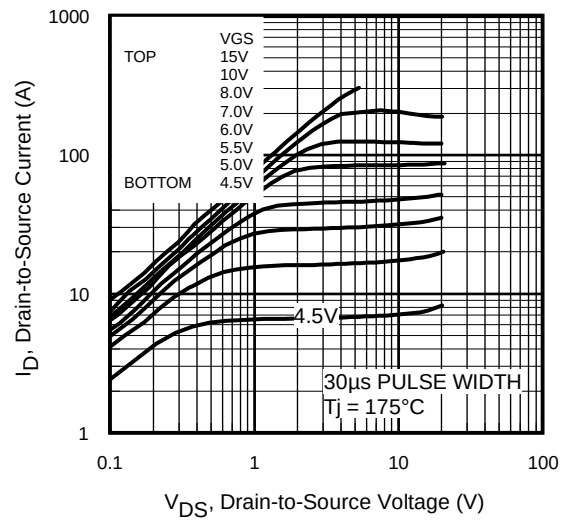
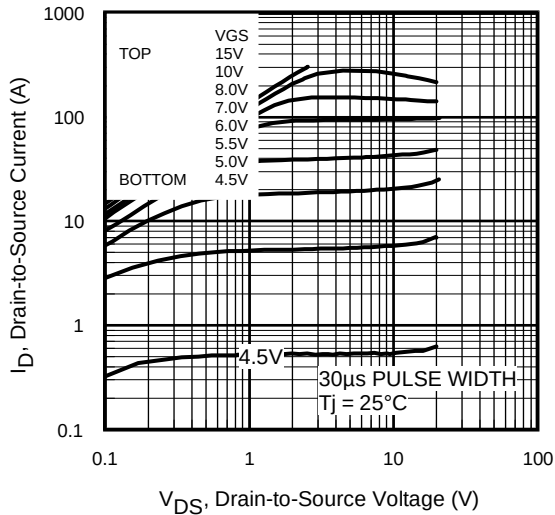
|                                 | Parameter                            | Min. | Typ.  | Max. | Units               | Conditions                                                                  |
|---------------------------------|--------------------------------------|------|-------|------|---------------------|-----------------------------------------------------------------------------|
| $V_{(BR)DSS}$                   | Drain-to-Source Breakdown Voltage    | 40   | —     | —    | V                   | $V_{GS} = 0V$ , $I_D = 250\mu A$                                            |
| $\Delta V_{(BR)DSS}/\Delta T_J$ | Breakdown Voltage Temp. Coefficient  | —    | 0.032 | —    | V/ $^\circ\text{C}$ | Reference to $25^\circ\text{C}$ , $I_D = 1mA$                               |
| $R_{DS(on)}$                    | Static Drain-to-Source On-Resistance | —    | 8.23  | 9.0  | m $\Omega$          | $V_{GS} = 10V$ , $I_D = 42A$ ③                                              |
| $V_{GS(th)}$                    | Gate Threshold Voltage               | 2.0  | —     | 4.0  | V                   | $V_{DS} = V_{GS}$ , $I_D = 250\mu A$                                        |
| $g_{fs}$                        | Forward Transconductance             | 32   | —     | —    | S                   | $V_{DS} = 10V$ , $I_D = 42A$                                                |
| $I_{DSS}$                       | Drain-to-Source Leakage Current      | —    | —     | 20   | $\mu A$             | $V_{DS} = 40V$ , $V_{GS} = 0V$                                              |
|                                 |                                      | —    | —     | 250  |                     | $V_{DS} = 40V$ , $V_{GS} = 0V$ , $T_J = 125^\circ\text{C}$                  |
| $I_{GSS}$                       | Gate-to-Source Forward Leakage       | —    | —     | 200  | nA                  | $V_{GS} = 20V$                                                              |
|                                 | Gate-to-Source Reverse Leakage       | —    | —     | -200 |                     | $V_{GS} = -20V$                                                             |
| $Q_g$                           | Total Gate Charge                    | —    | 30    | 45   | nC                  | $I_D = 42A$                                                                 |
| $Q_{gs}$                        | Gate-to-Source Charge                | —    | 9.6   | —    |                     | $V_{DS} = 32V$                                                              |
| $Q_{gd}$                        | Gate-to-Drain ("Miller") Charge      | —    | 12    | —    |                     | $V_{GS} = 10V$ ③                                                            |
| $t_{d(on)}$                     | Turn-On Delay Time                   | —    | 15    | —    | ns                  | $V_{DD} = 20V$                                                              |
| $t_r$                           | Rise Time                            | —    | 74    | —    |                     | $I_D = 42A$                                                                 |
| $t_{d(off)}$                    | Turn-Off Delay Time                  | —    | 30    | —    |                     | $R_G = 15\Omega$                                                            |
| $t_f$                           | Fall Time                            | —    | 38    | —    |                     | $V_{GS} = 10V$ ③                                                            |
| $L_D$                           | Internal Drain Inductance            | —    | 4.5   | —    | nH                  | Between lead,<br>6mm (0.25in.)<br>from package<br>and center of die contact |
| $L_S$                           | Internal Source Inductance           | —    | 7.5   | —    |                     |                                                                             |
| $C_{iss}$                       | Input Capacitance                    | —    | 1510  | —    | pF                  | $V_{GS} = 0V$                                                               |
| $C_{oss}$                       | Output Capacitance                   | —    | 340   | —    |                     | $V_{DS} = 25V$                                                              |
| $C_{rss}$                       | Reverse Transfer Capacitance         | —    | 190   | —    |                     | $f = 1.0MHz$                                                                |
| $C_{oss}$                       | Output Capacitance                   | —    | 1100  | —    |                     | $V_{GS} = 0V$ , $V_{DS} = 1.0V$ , $f = 1.0MHz$                              |
| $C_{oss}$                       | Output Capacitance                   | —    | 340   | —    |                     | $V_{GS} = 0V$ , $V_{DS} = 32V$ , $f = 1.0MHz$                               |
| $C_{oss\text{ eff.}}$           | Effective Output Capacitance         | —    | 460   | —    |                     | $V_{GS} = 0V$ , $V_{DS} = 0V$ to $32V$ ④                                    |



## Source-Drain Ratings and Characteristics

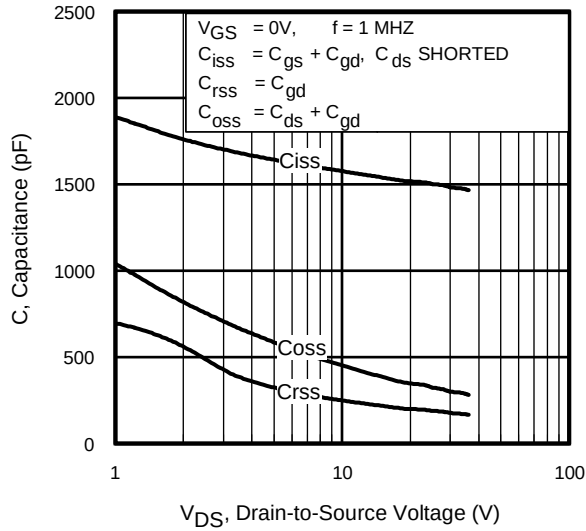
|          | Parameter                                 | Min.                                                                      | Typ. | Max. | Units | Conditions                                                              |
|----------|-------------------------------------------|---------------------------------------------------------------------------|------|------|-------|-------------------------------------------------------------------------|
| $I_S$    | Continuous Source Current<br>(Body Diode) | —                                                                         | —    | 42   | A     | MOSFET symbol<br>showing the<br>integral reverse<br>p-n junction diode. |
| $I_{SM}$ | Pulsed Source Current<br>(Body Diode) ①   | —                                                                         | —    | 310  |       |                                                                         |
| $V_{SD}$ | Diode Forward Voltage                     | —                                                                         | —    | 1.3  | V     | $T_J = 25^\circ\text{C}$ , $I_S = 42A$ , $V_{GS} = 0V$ ③                |
| $t_{rr}$ | Reverse Recovery Time                     | —                                                                         | 18   | 27   | ns    | $T_J = 25^\circ\text{C}$ , $I_F = 42A$ , $V_{DD} = 20V$                 |
| $Q_{rr}$ | Reverse Recovery Charge                   | —                                                                         | 9.2  | 14   | nC    | $di/dt = 100A/\mu s$ ③                                                  |
| $t_{on}$ | Forward Turn-On Time                      | Intrinsic turn-on time is negligible (turn-on is dominated by $L_S+L_D$ ) |      |      |       |                                                                         |



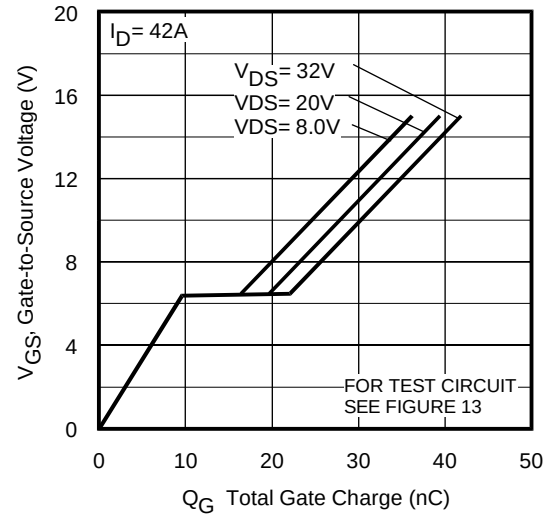


# IRFR/U3504Z

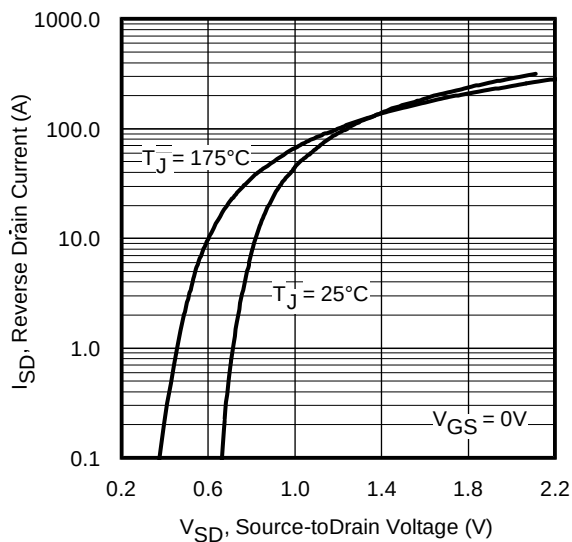
International  
**IR** Rectifier



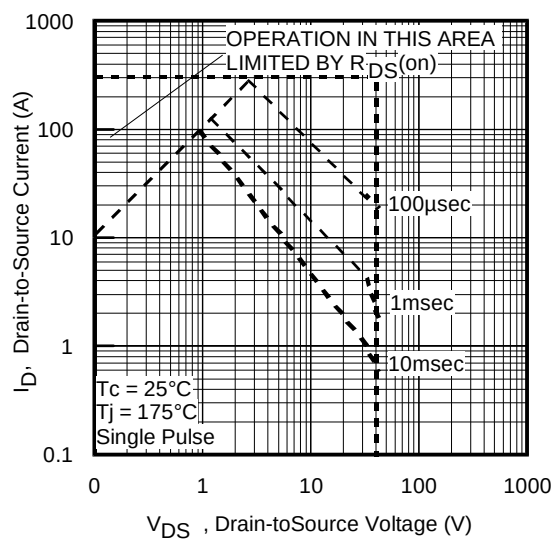
**Fig 5.** Typical Capacitance Vs. Drain-to-Source Voltage



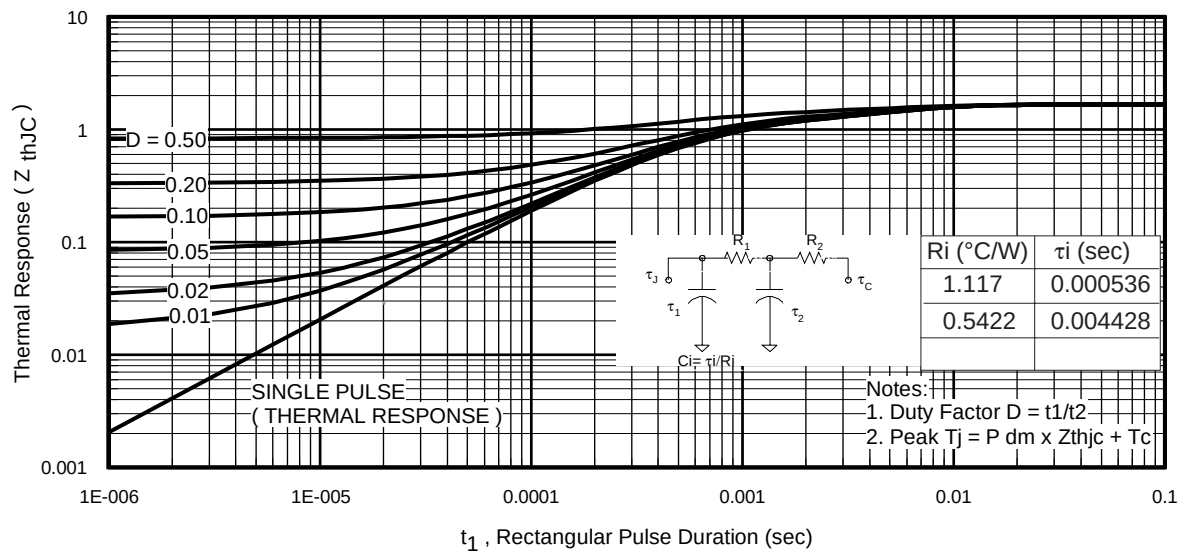
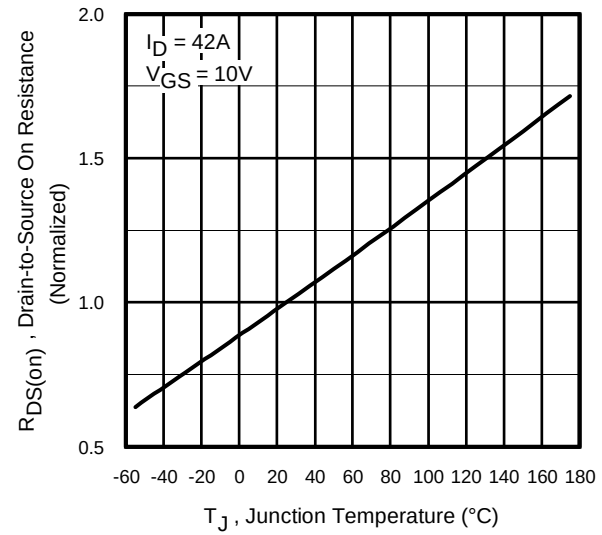
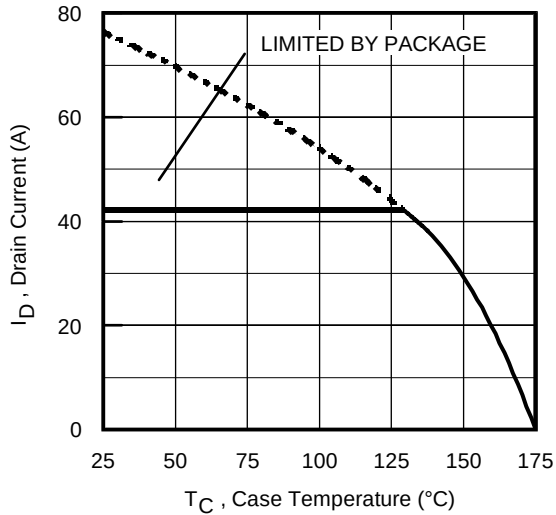
**Fig 6.** Typical Gate Charge Vs. Gate-to-Source Voltage



**Fig 7.** Typical Source-Drain Diode Forward Voltage

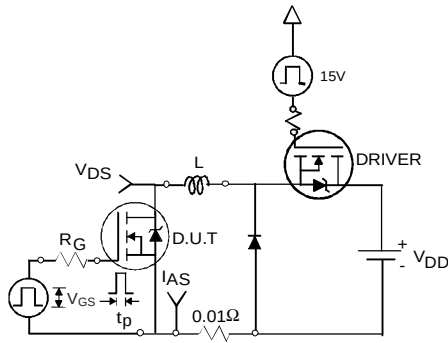


**Fig 8.** Maximum Safe Operating Area

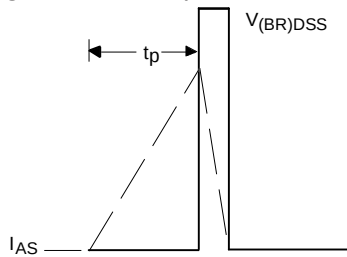


# IRFR/U3504Z

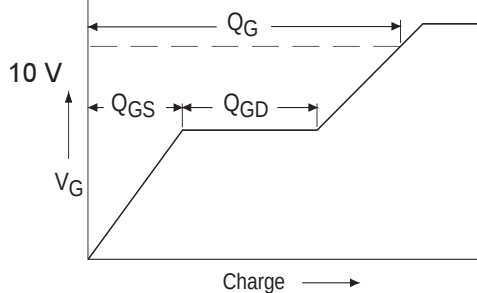
International  
**IR** Rectifier



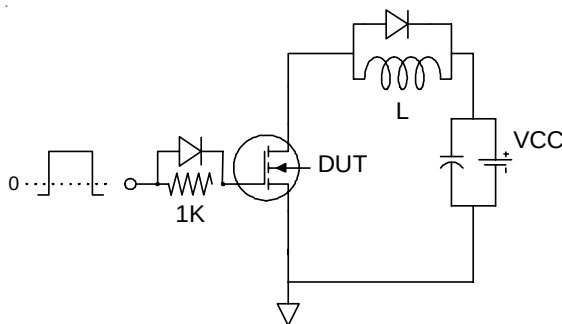
**Fig 12a.** Unclamped Inductive Test Circuit



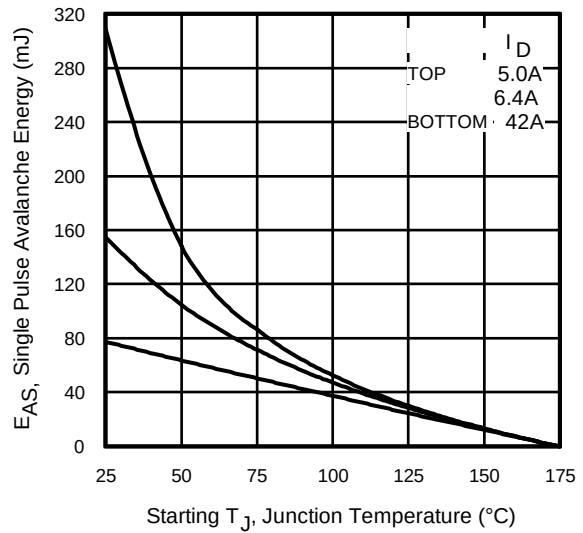
**Fig 12b.** Unclamped Inductive Waveforms



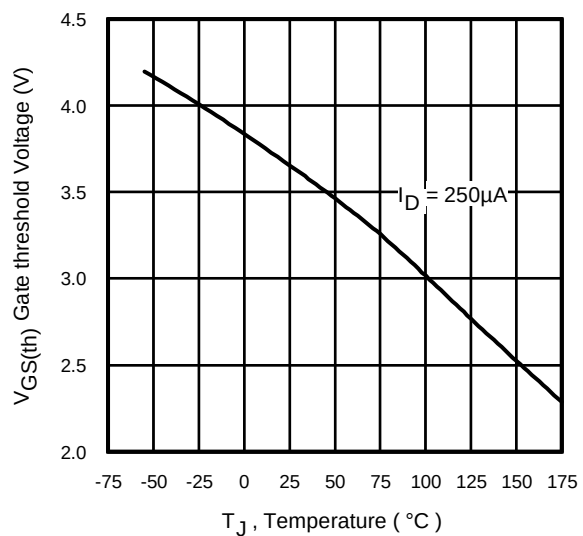
**Fig 13a.** Basic Gate Charge Waveform



**Fig 13b.** Gate Charge Test Circuit



**Fig 12c.** Maximum Avalanche Energy Vs. Drain Current



**Fig 14.** Threshold Voltage Vs. Temperature

www.irf.com

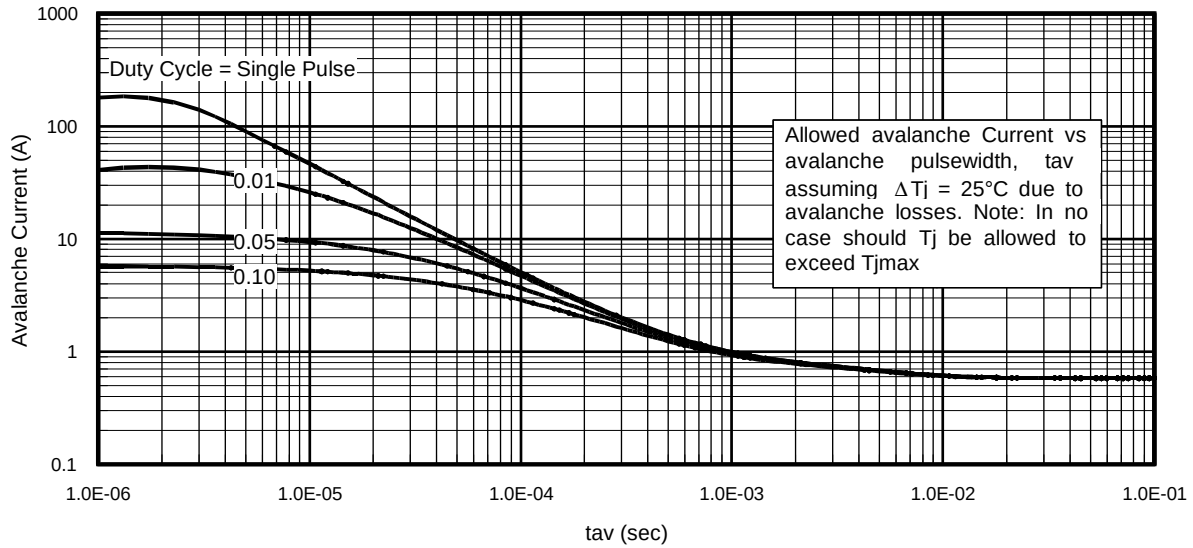


Fig 15. Typical Avalanche Current Vs.Pulsewidth

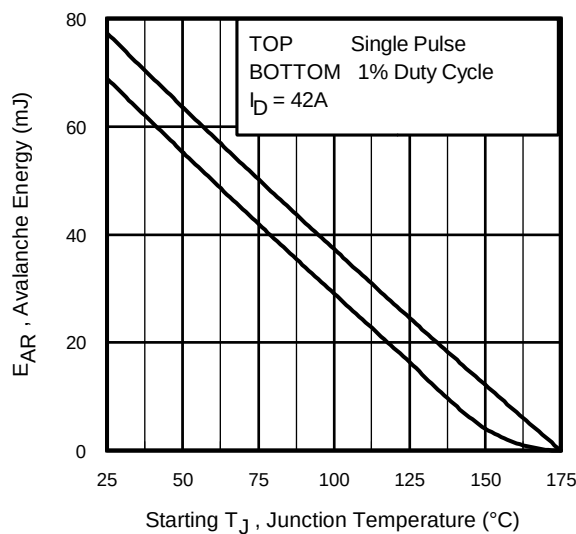


Fig 16. Maximum Avalanche Energy  
Vs. Temperature

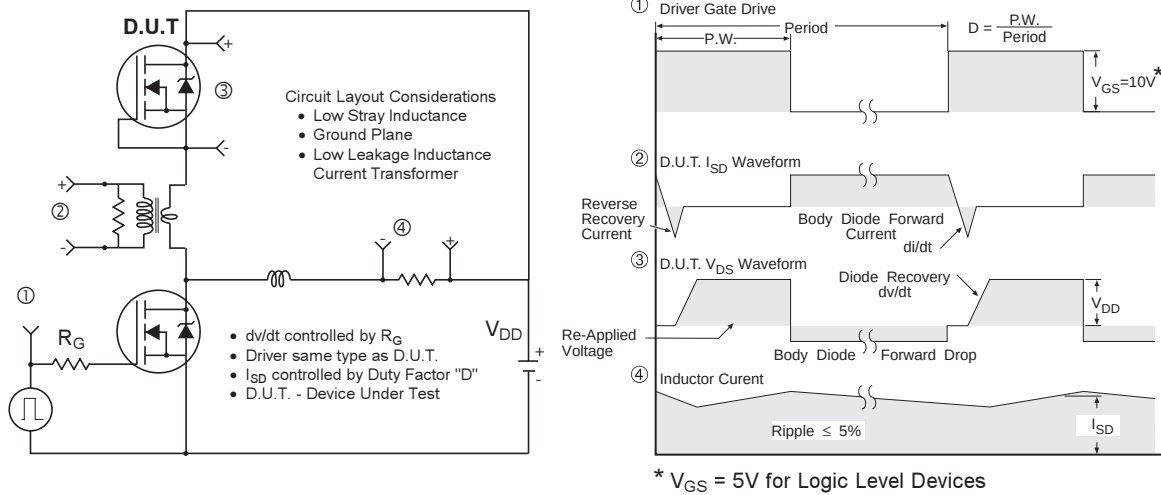
**Notes on Repetitive Avalanche Curves , Figures 15, 16:  
(For further info, see AN-1005 at [www.irf.com](http://www.irf.com))**

1. Avalanche failures assumption:  
Purely a thermal phenomenon and failure occurs at a temperature far in excess of  $T_{jmax}$ . This is validated for every part type.
2. Safe operation in Avalanche is allowed as long as  $T_{jmax}$  is not exceeded.
3. Equation below based on circuit and waveforms shown in Figures 12a, 12b.
4.  $P_{D(ave)}$  = Average power dissipation per single avalanche pulse.
5. BV = Rated breakdown voltage (1.3 factor accounts for voltage increase during avalanche).
6.  $I_{av}$  = Allowable avalanche current.
7.  $\Delta T$  = Allowable rise in junction temperature, not to exceed  $T_{jmax}$  (assumed as 25°C in Figure 15, 16).  
 $t_{av}$  = Average time in avalanche.  
 $D$  = Duty cycle in avalanche =  $t_{av} \cdot f$   
 $Z_{thJC}(D, t_{av})$  = Transient thermal resistance, see figure 11)

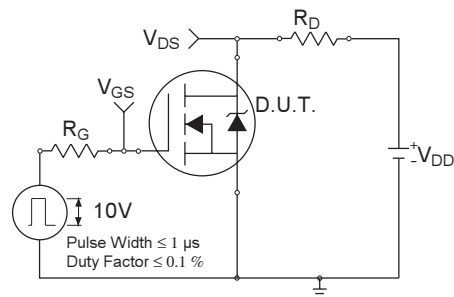
$$P_{D(ave)} = \frac{1}{2} (1.3 \cdot BV \cdot I_{av}) = \Delta T / Z_{thJC}$$

$$I_{av} = 2 \Delta T / [1.3 \cdot BV \cdot Z_{th}]$$

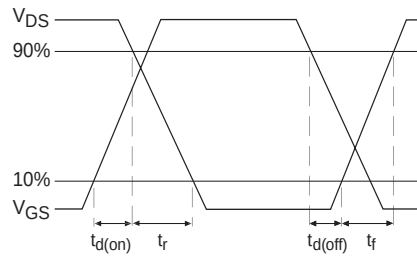
$$E_{AS(AR)} = P_{D(ave)} \cdot t_{av}$$



**Fig 17. Peak Diode Recovery  $dv/dt$  Test Circuit for N-Channel HEXFET® Power MOSFETS**



**Fig 18a. Switching Time Test Circuit**

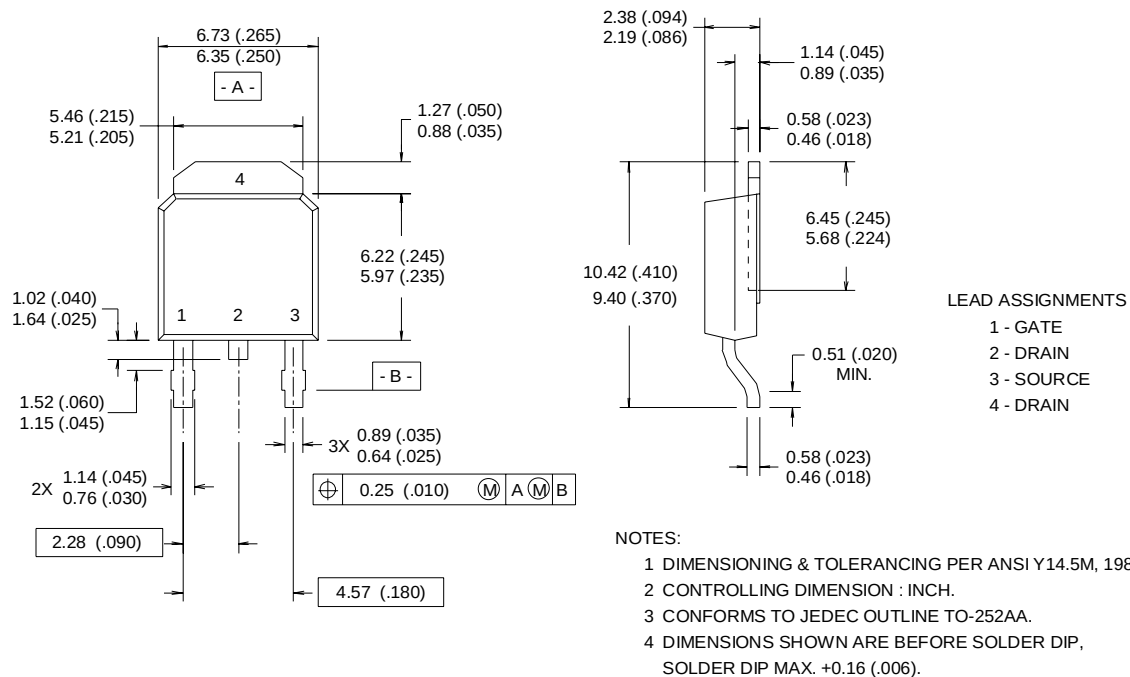


**Fig 18b. Switching Time Waveforms**



## D-Pak (TO-252AA) Package Outline

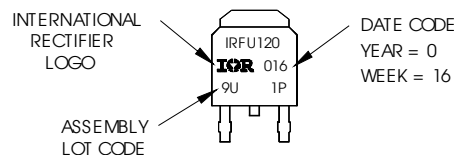
Dimensions are shown in millimeters (inches)



## D-Pak (TO-252AA) Part Marking Information

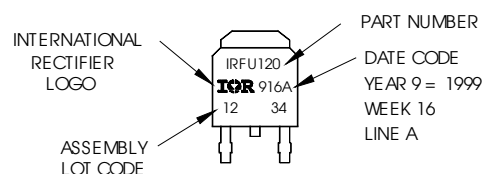
Notes: This part marking information applies to devices produced before 02/26/2001

EXAMPLE: THIS IS AN IRFR120  
WITH ASSEMBLY  
LOT CODE 9U1P



Notes: This part marking information applies to devices produced after 02/26/2001

EXAMPLE: THIS IS AN IRFR120  
WITH ASSEMBLY  
LOT CODE 1234  
ASSEMBLED ON WW 16, 1999  
IN THE ASSEMBLY LINE "A"

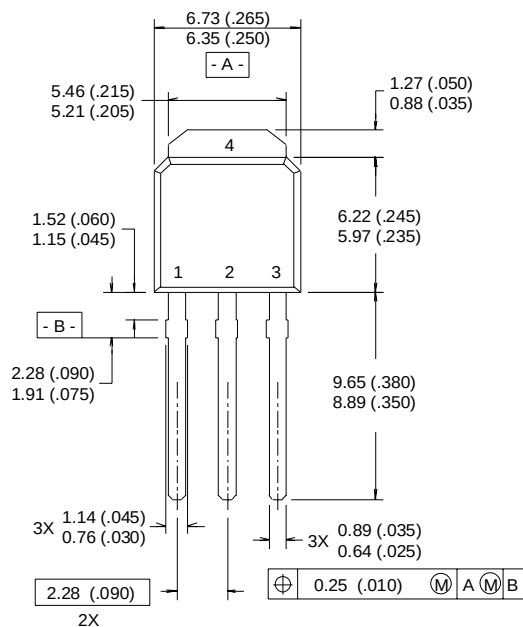


# IRFR/U3504Z

## I-Pak (TO-251AA) Package Outline

Dimensions are shown in millimeters (inches)

International  
**IR** Rectifier



### LEAD ASSIGNMENTS

- 1 - GATE
- 2 - DRAIN
- 3 - SOURCE
- 4 - DRAIN

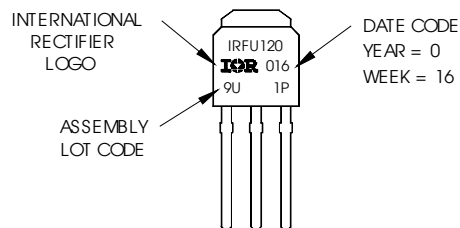
### NOTES:

- 1 DIMENSIONING & TOLERANCING PER ANSI Y14.5M, 1982.
- 2 CONTROLLING DIMENSION : INCH.
- 3 CONFORMS TO JEDEC OUTLINE TO-252AA.
- 4 DIMENSIONS SHOWN ARE BEFORE SOLDER DIP, SOLDER DIP MAX. +0.16 (.006).

## I-Pak (TO-251AA) Part Marking Information

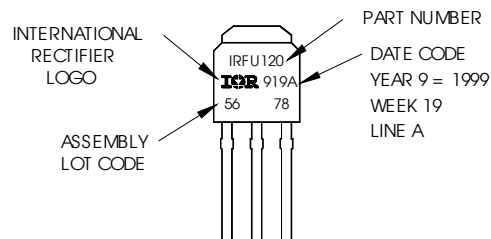
Notes: This part marking information applies to devices produced before 02/26/2001

EXAMPLE: THIS IS AN IRFR120  
WITH ASSEMBLY  
LOT CODE 9U1P



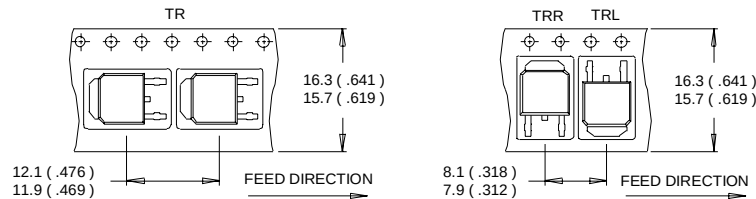
Notes: This part marking information applies to devices produced after 02/26/2001

EXAMPLE: THIS IS AN IRFR120  
WITH ASSEMBLY  
LOT CODE 5678  
ASSEMBLED ON WW 19, 1999  
IN THE ASSEMBLY LINE "A"



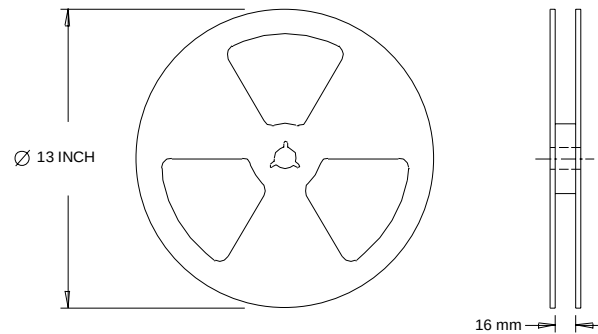
## D-Pak (TO-252AA) Tape & Reel Information

Dimensions are shown in millimeters (inches)



**NOTES :**

1. CONTROLLING DIMENSION : MILLIMETER.
2. ALL DIMENSIONS ARE SHOWN IN MILLIMETERS ( INCHES ).
3. OUTLINE CONFORMS TO EIA-481 & EIA-541.



**NOTES :**

1. OUTLINE CONFORMS TO EIA-481.

**Notes:**

- ① Repetitive rating; pulse width limited by max. junction temperature. (See fig. 11).
- ② Limited by  $T_{Jmax}$ , starting  $T_J = 25^\circ\text{C}$ ,  $L = 0.09\text{mH}$ ,  $R_G = 25\Omega$ ,  $I_{AS} = 42\text{A}$ ,  $V_{GS} = 10\text{V}$ . Part not recommended for use above this value.
- ③ Pulse width  $\leq 1.0\text{ms}$ ; duty cycle  $\leq 2\%$ .
- ④  $C_{OSS}$  eff. is a fixed capacitance that gives the same charging time as  $C_{OSS}$  while  $V_{DS}$  is rising from 0 to 80%  $V_{DSS}$ .
- ⑤ Limited by  $T_{Jmax}$ , see Fig.12a, 12b, 15, 16 for typical repetitive avalanche performance.
- ⑥ This value determined from sample failure population. 100% tested to this value in production.
- ⑦ When mounted on 1" square PCB (FR-4 or G-10 Material). For recommended footprint and soldering techniques refer to application note #AN-994

Data and specifications subject to change without notice.  
This product has been designed and qualified for the Automotive [Q101] market.  
Qualification Standards can be found on IR's Web site.